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Kinematic Analysis of Overhead Squat Patterns in Sarcopenic Older Women via 3D RGB-D Imaging

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Purpose

For functional assessment in clinical or home settings

- Traditional 3D motion capture → often costly, complex
- 3D RGB-D (Red-Green-Blue-Depth) imaging system → low-cost, markerless tool

This study compares overhead squat kinematics between sarcopenic and non-sarcopenic older women using a 3D RGB-D imaging system, and aims to provide sensitive metrics for monitoring rehabilitation progress in sarcopenic populations.

Methods

- ***Study design and setting*** : retrospective case-control study, January 2025 ~ August 2025, 64 patients, in single tertiary institute
- ***Sarcopenia diagnosis & evaluation*** : based on the Asian Working Group for Sarcopenia (AWGS) 2019 criteria
  - SARF-F, Calf circumference, Handgrip strength, SPPB, Skeletal muscle index (SMI)
- ***Squat protocol*** : 5-times consecutive overhead squats
- ***Outcome measures*** : Squat depth, Squat speed, Total vertical displacement, Head sway, Inter-knee distance, Knee flexion angle

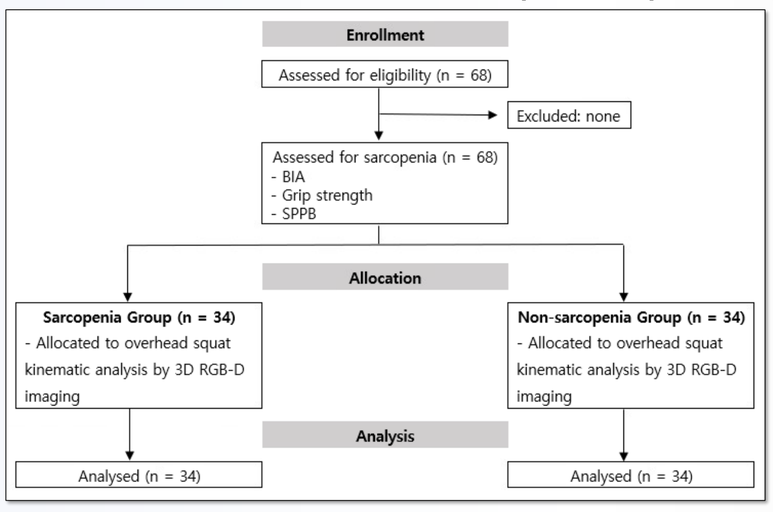

Fig. 1. Flow diagram of study.

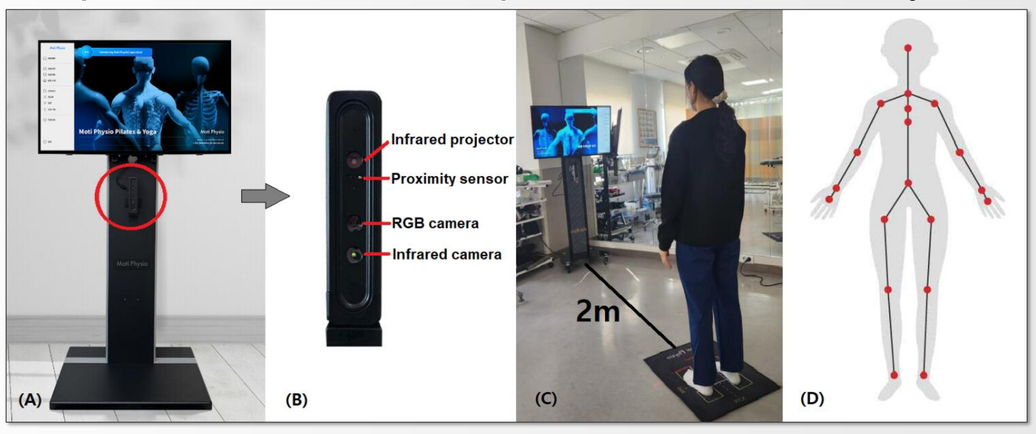

Fig. 2. 3D RGB-D imaging-based motion analysis system (Moti Physio, MG solutions, Seoul, Republic of Korea). (A) Front view. (B) Structure of RGB-D camera. (C) Overall appearance during test. (D) 19 points of markerless motion captured.

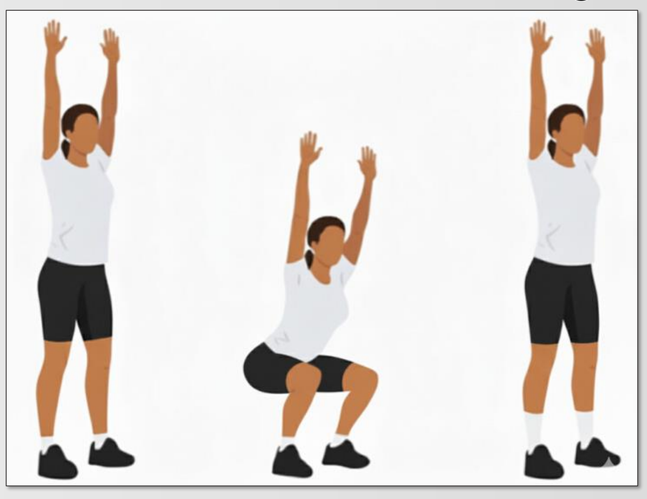

Fig. 3. Example of overhead squat motion, five times implemented.

Results

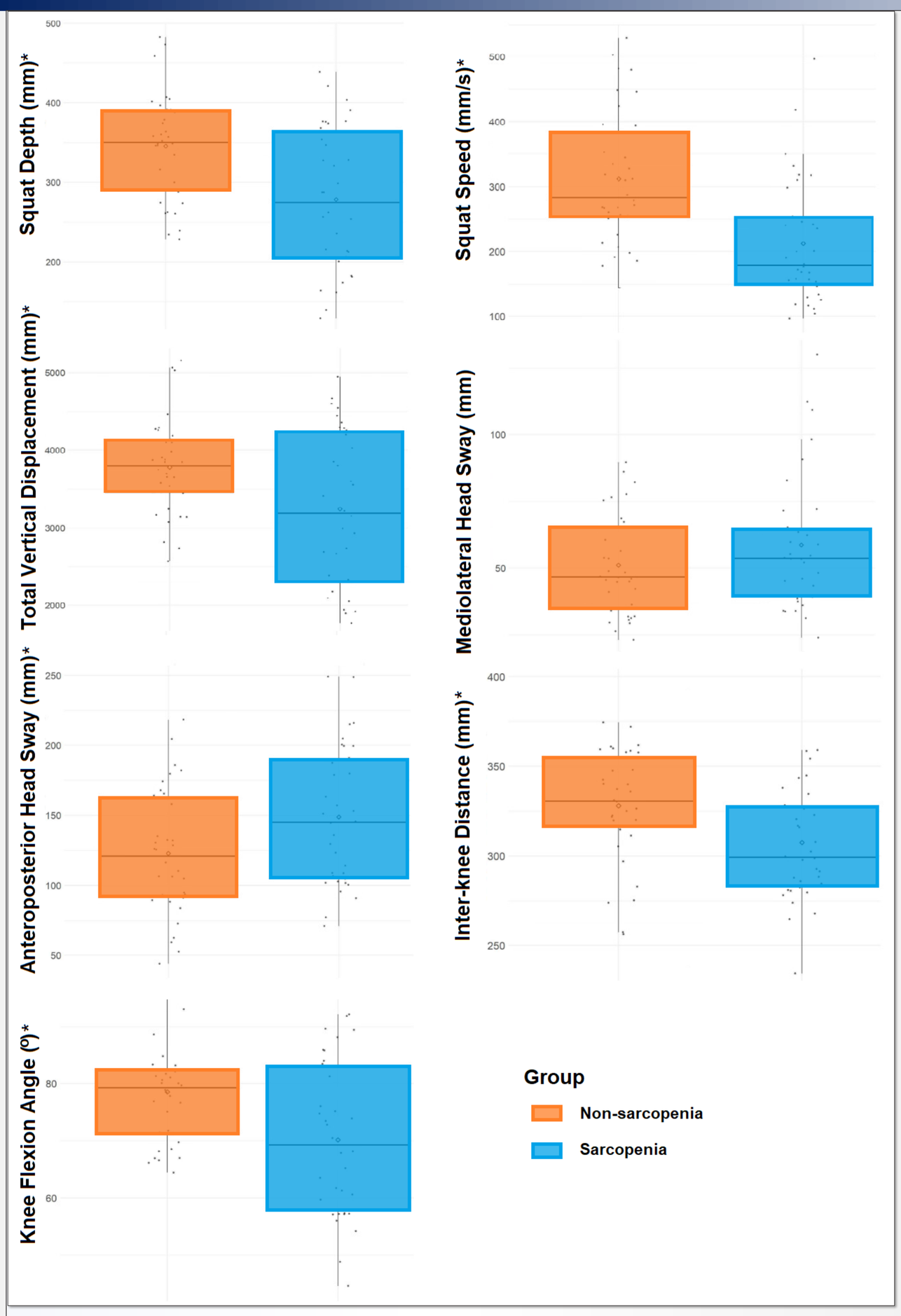

Fig. 4. Comparison of overhead squat kinematics between non-sarcopenia and sarcopenia groups. Box-and-whisker plots illustrate the distribution of kinematic parameters during the overhead squat task for the non-sarcopenia (orange) and sarcopenia (blue) groups. The horizontal line within each box represents the median, the diamond indicates the mean, and the box boundaries represent the interquartile range (IQR). Individual data points are displayed as jittered dots to show the distribution of the entire sample. *Significant at $p < 0.05$ by independent t-tests.

Table 1. Characteristics of Study Participants (N = 68)

	Non-sarcopenia (N=34)	Sarcopenia (N=34)	*p*-value
General Characteristics			
Age (year)	71.80±5.95	73.60±5.56	0.172
Height (cm)	156.97±5.21	154.56±4.76	0.064
Weight (kg)	61.30±9.72	55.10±10.88	0.016*
SARC-F score	1.35±1.02	3.34±2.42	0.000*
Calf circumference (cm)			
Right	34.63±4.84	32.51±3.16	0.043*
Left	34.62±4.77	32.43±3.14	0.034*
Grip Strength (kg)			
Right	18.95±4.76	15.12±3.30	0.000*
Left	18.64±5.49	14.47±3.37	0.000*
SPPB score	10.39±1.26	7.53±1.90	0.000*
SMI (kg/m²)	6.20±0.52	5.18±0.37	0.000*

SARC-F, screening tool for sarcopenia (strength, assistance walking, rise from a chair, climbing stairs, falls); SPPB, short physical performance battery; SMI, skeletal muscle index. Values are presented as mean±standard deviation. *Significant at $p < 0.05$ by independent t-tests.

Table 2. Results of Overhead Squat Kinematics

	Non-sarcopenia	Sarcopenia	*p*-value
Squat Depth (mm)	345.5±66.3	278.5±90.1	**0.000***
Squat Speed (mm/s)	310.0±102.5	212.4±95.3	**0.000***
Total Vertical Displacement (mm)	3781.8±622.9	3248.4±993.4	**0.010***
Mediolateral Head Sway (mm)	51.1±18.7	58.7±25.2	0.167
Anteroposterior Head Sway (mm)	122.9±44.8	148.8±49.5	**0.027***
Inter-knee Distance (mm)	328.0±31.4	307.4±34.8	**0.013***
Knee flexion angle (degree)	78.5±9.2	70.2±13.4	**0.004***

Values are presented as mean±standard deviation. *Significant at $p < 0.05$ by independent t-tests.

Conclusions

3D RGB-D imaging-based motion analysis system effectively quantifies kinematic differences in overhead squats, with sarcopenic groups showing significantly altered patterns due to reduced strength and impaired neuromuscular control. This **cost-effective** and **markerless** method may enable **early detection of motor decline** through longitudinal monitoring, and it may support **personalized, data-driven rehabilitation programs** through **home-based remote monitoring systems**.